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Interactive exercises in synchronous flow and constraint management

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Interactive Exercises in Synchronous Flow and Constraint Management

ABSTRACT

This interactive presentation will explain synchronous flow, line balancing, and constraint management followed by two hands-on exercises. The first exercise will be a line-balancing problem in which pairs of participants determine the number of workstations needed to meet daily production goals. The second exercise, groups of six to 10 participants will optimize a production line in a simulated environment to illustrate the effect of dependent events and statistical fluctuations.

INTRODUCTION TO SYNCHRONOUS FLOW, LINE BALANCING, AND CONSTRAINT MANAGEMENT

Many U.S. manufacturers are concerned with achieving high machine and worker efficiency. How would you design a system in order to achieve high efficiencies? How would you design a system in order to achieve flexibility and increase utilization? *The Goal* is an excellent source to draw upon while answering these questions. This paper will focus on techniques used in synchronous flow, line balancing, and constraint management. Below is a brief definition of each of these.

SYNCHRONOUS FLOW

Synchronous flow manufacturing is a pull system sometimes used to define the theory of constraints (TOC). It is based on years of industry best practices. Lean manufacturing is about eliminating waste, and synchronous flow manufacturing comes from lean thinking. The core concepts are grounded in simplicity—leading to quick understanding, implementation, and long-lasting success (Synchrono, 2002).

LINE BALANCING

Line balancing is the process of assigning tasks to work stations in such a way that the workstations have approximately equal time requirements (Stevenson, p. 279). Perfectly balanced lines have a smooth flow of work and activities to achieve maximum utilization of labor and equipment. What do you think is the biggest obstacle to achieving a balanced line? It is the difficulty forming bundles that take the same amount of time. There are many reasons for this difficulty including: (1) varying equipment requirements, (2) infeasible situations, (3) incompatible activity groupings, and (4) technological sequences prohibit ideal groupings. To understand the output rate of a line, one must know the cycle time, which is the maximum time allowed at each workstation to complete its set of tasks on a unit (Stevenson, p. 279).

PERFORMANCE MEASUREMENTS: THROUGHPUT, INVENTORY, AND OPERATING EXPENSE

In Eliyahu Goldratt's book *The Goal* (1986), there are many valuable lessons about throughput, inventory, and operational expenses. Next, concepts from *The Goal* you should understand relating to the hands on exercises will be discussed. What is the goal of the company? To make a profit.

There are three measurements that express the goal: (1) throughput (money inflow)—how does money flow into the system? Rate which the system generates money through sales, (2) inventory (money currently in system)—total investment in purchasing things intended for resell, and (3) operational expense (money outflow)—money you have to pay out to make the throughput happen.

In *The Goal*, a troop of Boy Scouts hiking a trail was analogous to a manufacturing system. The troop produces "walk trail." The first boy begins production by consuming the unwalked trail before him, which is the equivalent of raw materials. Each boy is like an operation that has to be performed to produce a product in the plant; each boy is one of a set of dependent events. Only after the last boy walks the trail is the product "sold." In this example, what is throughput? Inventory? Operational expense? In this example, throughput is the rate at which the last person walks the trail. Inventory is the amount of trail between the first and last boy. Operational expense is whatever lets them turn inventory into throughput, which in this case would be energy.

UNDERSTANDING BOTTLENECKS AND NON-BOTTLENECKS

A *bottleneck* is any resource whose capacity is equal to or less than the demand placed upon it.

Bottlenecks are not necessarily bad or good—they are simply a reality. The bottleneck flow should be equal to or slightly less than demand. Why? *If flow equals demand and the market demand goes down, you'll lose money.* A bottleneck is like an hourglass; hence, an hour lost at a bottleneck is an hour out of the entire system. Bottlenecks govern both throughput and inventory.

A *non-bottleneck* is any resource whose capacity is greater than the demand placed on it. The utilization of a non-bottleneck is not determined by its own potential, but by some other constraint in the system. When you make a non-bottleneck do more work than the bottleneck, you are not increasing productivity. On the contrary, you are doing exactly the opposite. You are creating excess inventory, which is against the goal.

PRINCIPLES IN UNDERSTANDING THE SYSTEM

1. Do not balance capacity with demand. Instead, balance the flow of product through the plant with demand from the market (i.e., balance flow with demand, not capacity). Therefore, excess capacity is needed.
2. "Utilizing" a resource means making use of the resource in a way that moves the system toward the goal. "Activating" a resource is like pressing the ON switch of a machine; it runs whether or not there is any benefit to be derived from the work it is doing. So, really, activating a non-bottleneck to its maximum is an act of maximum stupidity. Hence, utilization and activation are not the same.
3. A system of local optimums is not an optimum system at all; it is a very inefficient system.
4. If you consider the total time from the moment the material comes into the plant to the minute it goes out the door as part of a finished product, you can divide that time into five elements.
   a. Queue time: time a part spends in line for a resource while the resource is busy working on something else ahead of it.
   b. Setup time: time the part spends waiting for a resource, while the resource is preparing itself to work on the part.
   c. Run time: amount of time the part spends being modified into a new, more valuable form.
   d. Wait time: time the part waits, not for a resource, but to be moved.
   e. Move time: time to move the part to the next resource.
5. For parts that are going through bottlenecks, queue is the dominant portion. For parts that are only going through non-bottlenecks, they wait in front of assembly for parts that are coming from the bottlenecks. Which means that in each case, the bottlenecks are what dictate this elapsed time. Which, in turn, means that bottlenecks dictate inventory as well as throughput.
6. If batch sizes are reduced by half, what happens to processing time? It reduces by half. That means we reduce queue and wait by half as well. Reduce those by half, and we reduce by about half the total time parts spend in the plant. Reduce the time parts spend in the plant, and the speed of the flow of parts increases. And with faster turn-around on orders, customers get their orders faster. With shorter lead time, we can respond faster. If we can respond to the market faster, we get an advantage in the marketplace. That means more customers come to us because we can deliver faster. Our sales increase!

EMPLOYEES

With enough raw materials, you can keep one worker busy from now until retirement. But should you do it? Not if you want to make a profit. Making an employee work and profiting from that work are two different things.

LINE BALANCING WALKTHROUGH EXAMPLE

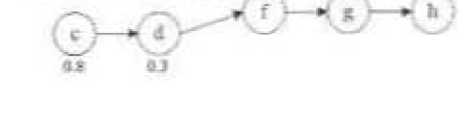
(Adapted from an example found in Stevenson, 6th edition, pp. 284-285.)

Using the information in Table 1, answer the following:

Task	Immediate Predecessors	Task Time (minutes)
A	-	0.2
B	a	0.2
C	-	0.8
D	c	0.3
E	b	0.6
F	D, e	1.0
G	f	0.4
H	g	0.3

Table 1.

a. Draw an activity-on-node (A-O-N) precedence diagram.



Station	Task	Time Required	Remaining Time	Remaining feasible tasks	Task w/ most followers
1	a	0.2	1.0	b, c	tie
	c	0.8	0.2	b	--
	b	0.2	0.0	--	--
2	e	0.6	0.6	d	--
	d	0.3	0.3	--	--
3	f	1.0	0.2	--	--
4	g	0.4	0.8	h	--
	h	0.3	0.5	--	--

b. Determine the minimum cycle time.
CT_{min} = 1.0 minutes

c. Determine the maximum cycle time.
CT_{max} = 3.8 minutes

Assume an eight-hour workday and a desired output of 400 units per day.

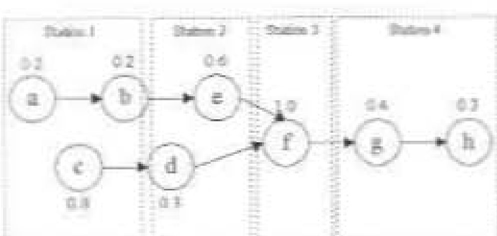
d. What is the desired cycle time?
CT_D = 480 minutes/day ÷ 400 units/day = 1.2 min. per cycle

e. What is the minimum number of workstations needed?

$$N_{min} = \left\lceil \frac{\textbf{400 units / day * 3.8 min./unit}}{\textbf{480 min./day / station}} \right\rceil$$

$$= \textbf{4 stations}$$

f. Assign tasks to workstations according to greatest number of following tasks. The tiebreaker is the task with the longest processing time.



g. What is the actual cycle time based on (f)?
CT_A = 1.2 minutes

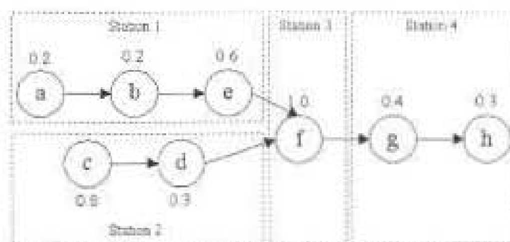
h. What is the efficiency based on (f)?
$E = 3.8/(4*1.2) = 0.7917$

i. What is the fraction of time idle based on (f)?

$I = 1 - 0.7917 = 0.2083$

j. What is idle time associated with each station based on (f)?
I_1 = 0 min., I_2 = 0.3 min., I_3 = 0.2 min. & I_4 = 0.5 min.

k. Determine a more natural line balancing.



l. What is the actual cycle time based on (k)?
CT_A = 1.1 min.

m. What is the efficiency based on (k)?
$E = 3.8/(4*1.1) = 0.864$

n. What is the fraction of time idle based on (k)?

$I = 1 - 0.864 = 0.136$

o. What is the idle time associated with each station based on (k)?
I_1 = 0.1 min., I_2 = 0 min., I_3 = 0.1 min. & I_4 = 0.4 min.

SYNCHRONOUS FLOW

During the presentation, there will be an explanation of dependent events and statistical fluctuations along with a small group simulation of a production line. Afterwards, a computer simulation of the interactive exercise will illustrate the various production strategies from which groups could have chosen.

CONCLUSION

At the end of this presentation, participants will be able to (1) identify the constraints within a production environment and their impact on throughput, inventory, and operational expense, (2) identify the minimum number of workstations needed to meet daily production goals given a list of tasks that need to be performed in order to make a product, and (3) demonstrate the impact of dependent events and statistical fluctuations within a production environment.

REFERENCES

Goldratt, E. (1992), *The Goal*, Second Edition, North River Press, Inc.

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